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Moderator: Jeff Nee
NOTE: Depending on if you are looking at the PPT or PDF, the slide number reference will need to be adjusted by +/-1.

Jeffrey Nee: Hello everyone. Happy Tuesday. This is Jeff Nee from Museum Alliance and it is our pleasure to welcome you to this telecon today. Thank you to all of you for joining us and to anyone listening to the recording in the future. Today we're hearing about the Mars InSight Mission. Very, very exciting. It's going to launch next year if all things go according to plan.

The slides for today's presentation can be found on the Museum Alliance and Solar System Ambassador sites. As always if you have any issues or questions now or in the future just email us. My email is jnee@jpl.nasa.gov.

Our speaker today is Dr. Bruce Banerdt but I always like to have Sarah Marcotte from the Mars EPO team to introduce our speaker. So Sarah Marcotte is our Mars EPO Lead and Sarah take it away.

Sarah Marcotte: Thank you Jeff. So I am just thrilled to have Dr. Banerdt because we are in the middle of a sort of practice run for this InSight lander. They are practicing how they would handle mission operations on sol 38, I guess 38 through 41 on Mars and so he has graciously stepped away from those meetings to join us today kick off our sort of ramp up for the InSight mission.

Dr. Bruce Banerdt has been trying to get a seismometer on Mars for 20 years. So he is a patient man and now he's getting his chance so we're very excited about that. He heads the InSight Lander Missions Science Team and he's also the lead for the SEIS instrument, which you'll be hearing about today which will be the first well-placed and functioning seismometer on Mars. Not the first one but the first one that's going to return some exciting data to us which will tell us about the formation of Mars and the inner rocky planet so it's a really exciting opportunity. And Bruce got his B.S. in Physics from USC and his Ph.D. also from USC so we can assume he's not a Bruin. And I will hand it over to Bruce. Thank you.

Bruce Banerdt: Okay thanks Sarah. So I probably have about an hour and a half's worth of material here so I'm going to have to go through it pretty quick and hopefully I'll have enough time at the end for some questions but we'll start off with looking at some things about the InSight mission science.

[Slide 2] So InSight is a mission to Mars but I really think of it as kind of a time machine and it’s a time machine in a couple of different ways. [Slide 3] In terms of what we're going to measure, really kind of going back to the start of the 20th century, back around 1900 when we were first doing seismology on the Earth and asking ourselves the questions of what was on the inside of the Earth and in particular - what was the thickness of the crust on the Earth, what's the structure of the mantle, the size and density of the core, and what's the distribution of seismicity or earthquakes around the planet. And when we're going to a new planet, Mars, we're asking ourselves these same kinds of basic questions about the planet and these are questions that we don't have the answers to yet.

[Slide 4] In terms of science goals, we go back even farther. We're going back almost 4-1/2 billion years and looking at the beginnings of our solar system and in particular the first ten to 100 million years of planetary formation and how the planet goes from sort of an agglomeration of dust in the solar nebula to the diverse objects that we see today.

Bruce Banerdt: So go on to the next slide [4] we have our - the InSight science goal and this is, the sort of my contract with NASA has a goal and then a set of what we call level 1 objectives and the overall goal is pretty simple: we want to understand the formation and evolution of terrestrial planets and we do that through investigating with seismology, precision tracking and heat flow and I'll go into each of those three in more detail.

Bruce Banerdt: [Slide 5] It's just kind of a plug I always put in and it's why it's really important to understand planetary interiors and I'm a little sensitive about this because we've gone to Mars, I don't know, you know, eight times in the past and we've, you know, done a lot of great exploration of the surface but we've never really gotten down below the surface and so InSight's going to be the first - the mission to Mars that's really going to sort of do more than scratch the surface.

Okay so [slide 6] terrestrial planets all share the same basic structure. They all have a metallic, mostly iron core. It's very dense, very hot. Around the core is the bulk of the planet which is what we call the mantle and that's made up of rocks that are a little bit denser than the types of rocks that we see on the surface generally because those are the rocks of the crust and these rocks are less dense and they're rocks that have been extracted from the mantle by various methods of volcanism and melting and so on.

And so even though we have lots of different types of planets in the inner solar system, we have hot planets, we have cold planets, we have, you know, dense planets and less dense planets, they all share the same basic structure and so this structure is something that's developed very shortly after they were initially formed and been maintained to the present. [Slide 7] And so that gives us a reason why we want to go to Mars to study the formation of planets.

It turns out that we have a lot of information about the Earth obviously but the problem with using the Earth to study the very earliest processes of planetary formation is that all the evidence has been destroyed, has been overprinted by the very vigorous plate tectonics, mantle convection, and so on that's really pretty much reformed the planet many times since its earliest formation.

We also have a lot of information about the moon and we've learned a lot about planetary formation on the moon except the problem with the moon is that information is limited because the pressure and temperatures inside the moon are not nearly as high, as large as they are in a terrestrial planet. If you go all the way to the center of the moon the pressure and temperature is really only about equivalent to going down about 200 kilometers in the Earth which is not very far when you consider the radius of the Earth is about 6700 kilometers. And so the moon doesn't tell us very much about what's happening inside a planet except for the very outermost layers.

But Mars is large enough to have enough pressure and temperature to undergo the same processes as the Earth and the larger rocky planets but is not so large and not so active that it's erased that information. And we have date from Mars meteorites and from geological investigations of Mars that indicate that the structure that we see today in the planet is of the same age, around 4.3 to 4.4 billion years old as the formation of the planet. So it's not too big, it's not too small, it's just right so we like to call it the Goldilocks planet.

[Slide 8] Okay so how does the terrestrial planet form? It starts forming through accretion of meteoritic material. So this is the stuff that the dust and small rocks that are orbiting the sun very early in the history of the solar system, they start to accrete and clump together through gravity and as they clump together it starts to heat up, both from the overpressure of the materials that accumulates and also from the energy of the impacts as these various different rocks impact the surface. And finally, through the action of radioactive materials that are included in the rocks that as they decay they heat up as well so these bodies get larger, they heat up, then a bunch of stuff happens and the planet ends up with a crust, mantle and core with this distinct non-meteoritic composition.

So when this stuff happens that's where InSight comes in. Those processes are not very well understood right now and we want to use InSight to provide some information for a lot of the models that are out there on planetary formation that will teach us about how planets formed.

Just kind of an interesting sidebar: people don't think about it but when the planet formed, the planet formed almost exclusively from sort of a C1 type carbonaceous chondrite material but if you pick up any rock on the Earth today it will not be the same composition, the same minerals that in a Cd1 chondrite. All these rocks, everything that you can find on the Earth has been reworked through a process called differentiation.

And that's illustrated on slide number [9]. This is a theory that was developed to explain the rocks that we've brought back from the moon back in the 1970s and the idea is that the planet gets hot enough to melt or partially melt itself. As it gets very hot the reduced metallic material condenses into droplets or larger bodies that then sink down to the bottom because they're much more dense to form the core. Then as the molten silicate material which makes up most of the planet starts to cool. It has a very complex process of physical chemistry that changes the mineral content which is essentially the way that that the atoms form themselves into crystals which is dependent on pressure, on temperature and it's dependent on the actual composition of the melt.

And so as the different materials crystalize out they change the composition that's left behind and that changes the way different crystals come out and sometimes they can get mixed back in, re-melt, recrystallize and it's a very complex process that we want to understand. And when you get done you end up with this dense core, this somewhat less dense mantle and then a very much less dense crust that forms a planet and understanding this process of differentiation is really kind of key to InSight science goals.

Slide number [10] shows a comparison of the Earth, Moon and Mars and the main point of comparison I want to point out is if you look at the various different parameters for Mars they all have question marks after them. On the Earth, we know the structure very well. On the moon, we know it actually pretty well too. On Mars basically everything is a question and we have - I have an indication of our uncertainty on each of these things and sometimes these uncertainties are extremely large compared to our knowledge. And so with InSight what our goal is is to actually get rid of all these questions marks and actually have real numbers just like the Earth and the moon.

Okay on slide [11] it goes into a little bit more detail. So this is an illustration of how the basic structure provides key information about formation evolution.

Bruce Banerdt: So for example understanding the crust thickness and layering that tells you something about the depth of crystallization, the depth of melting and crystallization because the crust is sort of a distillate. It's something that is kind of extracted from the mantle and sort of the more of the mantle that's been melted sort of the thicker the crust is going to be. And so just knowing the thickness of the crust tells the very basic fact about the processes very early in Mars' formation.

Bruce Banerdt: So we're on the slide that says Basic Structure Provides Key Information About Formation and Evolution. Okay so in terms of the mantle, the behavior of the mantle in terms of things like convection and the generation of partial melt which powers volcanism determines how the thermal history has run out on the planet's surface and that depends on the thermal structure of the mantle and the thermal structure is the temperature as a function of depth and the stratification of the mantle and that is whether you have, layering of different kinds of rocks as you go down the mantle or whether the whole mantle has been mixed up through a process like convection or something like that.

And finally the core size and composition which we can get at through its density reflect the conditions of the accretion of the planet and the very early differentiation. So the state whether it's liquid or solid reflects a composition because if you have impurities in the iron core it's going to actually change the melting temperature of the core and it also reflects of course the thermal history of the planet and how much heat is in the core.

And so if you go to the next slide which is called Direct Linkage Between Science Objectives and Level 1 Requirements, those various different things that were in red bold on the previous page map straight into this list of ten level 1 requirements that when I proposed this mission to NASA I said if you fly this mission these are the ten things that we will be able to determine from this mission at least if nothing else. And so these are level 1 requirements and by satisfying these requirements, by making these measurements we'll be able to use these measurements to understand early planetary differentiation through the kinds of things that I spoke to the previous page.

So next I want to talk about the payload and just skip through the title slide. Insight Payload Configuration: this shows an artist's rendition of our spacecraft which is the same design as the Phoenix spacecraft. It has the same landing system, the same power system, et cetera. All we've done is we put a different set of scientific instruments on it than Phoenix and are reusing this design which helps us to save some money and to be able to have more money left over for science.

So the three main instruments on the spacecraft are the SEIS which is the seismometer shown at sort of the bottom right of the picture, the HPQ which stands for Heat Flow and Physical Properties Package which is our mole which drills down and measures the heat flow of the planet, and RISE which is our Radio Science Experiment. It actually just uses our communication system to send radio signals from the deep space network to the spacecraft and back again to do very precision tracking of the spacecraft to understand the dynamics of the planet, the wobbling.

But in addition to these three instruments we actually have a lot of other things that support our experiments. We've got a robotic arm, we've got two cameras, we have the mechanisms on the arm to move the instruments from the deck to the ground. We also have a magnetometer. We have a whole weather station which measure the air pressure, the air temperature and wind direction and speed, and a radiometer that measures the temperature of the ground.

The final thing on our payload which may be of a lot of interest out there is our Names to Mars chip. So we already have a chip that we filled up with names for our original launch opportunity back in 2016 but we're opening that up again pretty soon to put together a second chip for people who didn't get in on it the first time. So we'll be sending a bunch of people's names to Mars micro-engraved on a chip.

The next slide says Seismometer Sensitivity and this is just to give you an idea of just how sensitive the instrument that we're sending to Mars is. What we measure with the seismometer is the displacement of a mass which is hanging off of a spring with respect to the ground. So as the ground moves up and down, it accelerates up and down the mass tends to stay still through inertia and we can measure the change in the position of that mass with respect to the ground. And with the sensitivity of that measurement is about 2-1/2 times 10 to the minus 11 meters which translates to about half of the radius of a hydrogen atom, okay? So and I like to tell people that's not the diameter, that's the radius. It's actually even smaller than you think.

So we're actually measuring vibrations of the ground, motion of the ground at a level of less than an atomic size and so that's how sensitive a seismometer is which sounds crazy but I wouldn't believe it either except we actually do it on the Earth all the time. So seismometers that are distributed around the Earth measuring earthquakes actually have a sensitivity like this.

And just another sort of indication of just how sensitive these seismometers are this is a seismic record that we took over a few days at Lockheed Martin when we were trying to figure out just how seismically noisy their assembly floor was. And this is a record that goes from over five days in March - oh including over a weekend and the colored part is actually - it's a spectrogram. So you have time going across the bottom as you go from left to right and the vertical access is the frequency spectrum.

So at the very bottom it's very long period-ways. As you go up to the top it gets the higher and higher frequencies of vibrations and you can see the vertical lines. Those are quakes or people driving to work. Where it says cultural noise that means - basically cultural noise means the workday starts and the workday ends and what you're seeing are cars driving back and forth next to the building.

But that kind of blue band that runs through the center of the picture and is there kind of all the time, that's actually the noise from the ocean hitting the coastline and this is in Denver, Colorado and so the coastline is not very close. So we're actually hearing the waves that are hitting the coastline almost 1000 miles away. So that's how sensitive seismic measurements are.

So the next slide shows some of the insides of the seismometer. So it's little bit more complicated than that mass on a spring. The sensor head assembly up in the upper left is what the thing looks like when it's all put together. But in the upper right is sort of the heart of that instrument. It's what we call our VBB for very broadband sensor and that's about the size of your fist and that's what does the measurement that I was talking about. And we have three of those inside of an evacuated sphere and that is then connected to the LVL which is our leveling system which levels it on Mars so that we don't have gravity pushing the sensors one way or another. And so it's a very complex instrument which actually gave us a lot of headaches working out all the bugs but we've got it now.

The next slide shows some of the other components in terms of we have the electronics. We also have several things that protect the seismometer from the environment. The R-WEB is a thermal protection. The WTS is wind and thermal shield. It looks like a big wok that we put over the top of it and it's kind of interesting because you can see that kind of silver skirt around the bottom, that's actually made of chainmail like they had in medieval armor and that allows this flexible skirt to drape over rocks and kind of seal around them so the wind doesn't come in underneath the skirt.

And finally, we have across the bottom it shows the tether which the whole thing is about four or five meters long that connects the seismometer from the ground up to the spacecraft and then it snakes inside the spacecraft to the electronics which is kept in an insulated box inside.

So Martian seismology is a very immature science since we never actually have gotten any seismic data from Mars but we think there's lots of different sources of seismic waves on Mars. The first is just faulting which is a kind of thing that we get on the Earth from earthquakes. We expect to have Mars quakes. The plot here shows basically how many Mars quakes we hope to see. Seismic moment on the bottom is a measure of the energy in a quake and that corresponds to magnitudes on the top so you can see sort of a magnitude: 3 earthquake magnitude up to magnitude 6 is kind of the range of earthquakes that we hope to see on Mars.

And the lines show the number and so the number on the side in log scale, you can see it goes from 10 to the zero in the center which is 1 and we go up to - oh the higher - so the gray bar is kind of where we expect to be on Mars, so for a magnitude 3 earthquake we expect to see maybe 100 of those at our seismometer over the course of a year whereas if you want to see a magnitude 6 which is really great and has a lot of information we may see less than one of those per year. So we may have to be around for quite a while to see a magnitude 6 earthquake.

So these are all from theoretical calculations. We won't really know where we'll be until we actually go on Mars but you see the red line is what we see on the Earth. Once you get off plate boundaries the little purple line is what we see on the moon and so we're kind of in between those so we are pretty sure we'll be somewhere in that range.

But even if we don't see Mars quakes which is unlikely there's other things that we'll get signals from. Meteorite impacts along the bottom: we know that we have meteorites impacting Mars today. The plot on the left there on the bottom shows the meteor craters that have been seen by the Mars Reconnaissance Orbiter since it went into orbit. So these are places where we have a before and after pictures where it shows a smooth plane before and then later on they've taken the image of the same area and they've found an impact.

And so there are several hundred of these that they've actually seen with Mars orbiters in the time that they've been up there and each time you get an impact that's going to generate seismic waves they're smaller than Mars quakes in general but we still can calculate that we'll see somewhere between several and maybe a couple of dozen impacts during the course of our mission and we can use the waves from those impacts to probe the interior the same way that we use seismic waves.

And finally, we have the Phobos tide. Every time Phobos goes over it actually flexes the crust and the amount of flexure in that crust is related to the size of the core it turns out and so we can use the Phobos tide which is a guaranteed signal to probe the interior.

And last but not least, if you've run the little video that's a modeling of the atmospheric dynamics, the pressure on Mars over a 10 by 10-kilometer square and as that pressure is pushing up and down on the ground it actually is shaking the surface of the planet and generating seismic energy and that seismic energy turns out to organize itself into resonances and those resonances can be used to understand the structure of the planet.

Talk about that a little bit more in the next slide which is labeled Martian Seismology and this shows that there's a whole bunch of ways to actually use seismology to understand things about the structure of the interior. Most of them have to do with resonances of one kind of another.

The background hum, that's what we get from the atmospheric excitation and that's sort of a background vibration that's there all the time and the frequencies of the resonances that we can see in that are related to the structure as you go down, the elastic and density structure as you go down as are the normal modes which is another word for resonances. Surface waves are another kind of - it's a traveling wave but it's - again it has resonances which cause it to organize into wave trains which can travel faster or slower depending on their wavelength and we can use that to measure the thickness of the crust.

But the most important technique is in the center which is arrival time analysis and that's the normal way that you do seismology on the Earth. The thing that people don't realize, I mean, most people who know anything about seismology at all know that you need at least three stations to do seismology so that you can triangulate on the location, the epicenter of the quake and once you know the epicenter you can start measuring the travel time to your station and from that you get the seismic velocities and the seismic velocities are what are related to the density and the elastic constants which we can then relate to actual rock types.

Okay so we only have one station on Mars so how do we go about doing seismology with only one station? If you go to the next slide, Event Location and Seismic Velocities, this shows how we're doing the trick on Mars. And Mars helps us out by being a smaller planet which allows a little bit different kind of seismology than on the Earth.

And so you can see on this diagram you have the red and yellow arrows which are the P- and S-waves. These are called body waves and they basically travel straight from the source which is a star - that's the Mars quake travels more or less straight through the planet. It actually travels in a curve but I'm not good enough with PowerPoint to make curvy arrows.

So it travels to your station which is that triangle and you get the P-wave arrives first, S-wave arrives a little bit later but if that's all you know - you know the time when those waves occur at your station you don't know when they started at the beginning.

So we also have the surface waves which are the R-waves for Rayleigh waves. We have one surface wave that travels the short way around the planet which is the blue arrow. We have another Rayleigh wave which goes the long way around the planet, so it arrives a little bit later than the R one. And finally, we have the wave that travels - the R3-wave which travels from the source to our station and then keeps on going all the way around the planet and comes in a long time later to give us an arrival for R3.

Now we've got five measurements and our measurements are times of arrival. We have five parameters that we wanted to determine which is the velocity of the Rayleigh wave, the velocity of the P-wave, the velocity of the S-wave, the distance and the origin time and those are the things that we need to know in order to understand what's going on inside the planet. And if you’ve had algebra you know if you have five equations and five unknowns, so five measurements and five unknown quantities you can actually solve for that group. So you don't have to have three stations to get the P and S arrival times to triangulate back to the event.

Okay so that's it for seismology for now. We have a heat flow measurement. The heat flow probe has a self-penetrating mole which is like a little torpedo about a foot and a half long that has a hammer on the inside. It hammers itself down into the soil and pulls behind it a cable which has temperature sensors. These measure the temperature every 35 centimeters deep. That allows us to determine the thermal gradient. So that's the increase in temperature as you go down in the planet.

So we're only going down about 15 or 16 feet but in that 15 or 16 feet the temperature is going to go up by a very small amount but that's a measurable amount and by measuring that amount we can actually extrapolate that deep in to the planet to understand how much heat is coming out the planet and by that to infer the temperature distribution as a function of depth.

The next slide, The Mole in the science tether, this shows a picture of some of the stuff and I don't have time to go into any detail. Our third experiment is the radio science experiment. As I've mentioned before we measure the timing and the Doppler shift of the signal that's sent from the DSN to the lander on Mars which then turns it around immediately and sends it back.

By using techniques that they've refined over the last 50 years they can actually locate where that lander is in inertial space to an accuracy of better than 10 centimeters which is another crazy, crazy thing and it's kind of hard for me to believe but I've seen it happen and so we can measure this thing.

As you measure the location of the spacecraft, in this case it's attached to the surface so you're really measuring the motion of the surface of Mars and in particular you're measuring the rotation of Mars. And so we measure it over an hour which gives a little arc as it moves around its axis rotation, then we can then use to locate where the spin axis is pointing and how fast the planet is spinning.

So we go to the next slide, The Precision Radio Tracking: we then can measure the variations in the rotation axis. So the rotation axis precesses which is what a top does when it wobbles, and that procession takes about 165,000 years which is pretty slow but by measuring it today and looking at the similar measurements we did at Pathfinder about 20 years ago and the same measurements we did on Viking which was 20 years before that we could actually see the small amount of change in that rotational pole, the north pole of Mars over that time and we can measure that precession rate.

Turns out the precession rate is related to the moment of inertia which is related to basically the size and density of the core of Mars. Unfortunately, moment of inertia is the size and the density multiplied together so we can't get them separated but we can actually separate those if we measure the next size of the wobble which is sort of a wobble on top of a wobble and a small wobble is called a nutation and that happens on timescales of less than a year. And so it's a much smaller motion but by measuring that wobble we can actually get the moment of inertia of the core by itself and by having those two quantities together we can separate out this core size and density.

Okay so I'll give a little description of the mission itself and then we can go to questions. So I'm on slide 26 which says InSight 1.0 Becomes InSight 2.0. Many of you may know that we originally were slated to launch in March of 2016 but we had a lot of difficulty in getting our seismometer assembled and working properly and we were about nine months late delivering that seismometer to the spacecraft.

And right about a week before that delivery in late August we found a very tiny leak in the vacuum vessel containing the seismic sensors. And these sensors are so sensitive that if you have any gas in the sensor itself that gas provides friction and it damps the motion of these masses on the spring to the point where we lose the sensitivity that we need to make our measurement.

We tried to fix the leak but by December it was clear that we weren't going to be able to do it in time so we had to abandon the 2016 launch. And the size of this leak, just to give you an idea, if your tire was leaking at the rate that the seismic sphere was leaking it would be 50 years before you noticed the 1 psi change in the pressure of your tire. But that was enough to completely destroy the sensitivity of the instrument.

So we did a very quick and intense re-planning effort. I went back to NASA and requested an extension to our launch. You probably know the Mars launches can only occur every 26 months or so due to the alignment of the planets so they gave us another extension of our mission to launch in 2018 and we've been working since then. We remanufactured our vacuum container, fixed the problem that we had and now the seismometer's been completed, it's been fully tested now, it's leak-tight and it's actually been installed on the spacecraft.

Okay so the mission summary: we're going to fly - as I said a very close copy of the successful Phoenix lander we're launching in a time period between May 5th and June 8th of next year so we hope to launch on Cinco de Mayo.

It's a little bit unusual. We're actually launching from California, from the Vandenberg Air Force Base in California and the reason we can do that is because the Phoenix spacecraft was designed for a relatively small rocket called a Delta II but since Phoenix they've stopped making those rockets and so the only rocket that we have that's appropriate is about twice as powerful as the Delta.

And so instead of having to use a launch that is near the equator and launches to the east which uses sort of the rotation of the Earth as kind of a slingshot as what happens on most planetary launches, we can actually launch into a polar orbit. We launch almost due south from Vandenberg and we have enough energy in our rocket to do that without the help of the Earth and that's actually a lower cost option for NASA because the Vandenberg site is easier to use and there's a big traffic jam of rockets trying to launch out of Cape Canaveral. So that actually makes things easier in a lot of ways. Plus it's an easy drive from JPL so that makes it a lot more fun.

We're landing on November 26th. Anytime we launch in that window we're going to land on the same day. It's two days after Thanksgiving next year. We have a two-month deployment phase and I'll talk about the deployment phase in a minute and then after we get our instruments working we have two years which is about one Mars year of measurements on the ground. It's repetitive operations to save cost. All we do is sit there very quietly and listen with our seismometer and our heat flow probe, make our tracking measurements, and accumulate data over two years of operations and putting our nominal end of the mission in November of 2020.

Let's see and I think at this point we should run the first video. If you get that up you can go ahead and start it and it shows the way that we land. So this shows the probe going towards Mars. It ejects the crew stage and then enters the atmosphere. You can see the heat shield start to heat up as we enter the atmosphere. It uses friction to slow it down. Once it gets to about twice the speed of sound it actually releases a parachute, a supersonic parachute which is very close to the design of all the parachutes.

At some point, we drop our heat shield. We have a radar that tells us when we're about 2 kilometers up then we release from the shoot. Then we fire off our rockets and land gently on the surface, hopefully very gently on the surface sort of in a normal way, no airbags, no sky crane. This spacecraft sets down like a regular rocket. After we're on the surface we open up the solar panels which are kind of a Japanese fan kind of affair and we're ready to operate on the surface of Mars.

So if we go back to the PDF presentation we're now on slide 28 which is Landing Site. Western Elysium Planitia shows where we're landing on Mars. This is a very smooth plane. Unlike most missions to Mars we're not interested in the geology so we're going to the flattest, most boring, safest landing spot we can find. It's about 350 to 400 kilometers north of Curiosity so we actually have a lot of company on the surface of Mars and our landing ellipse you can see is threaded in between a bunch of craters but it's very few craters inside the area that we expect to land.

The next slide on Surface Deployment- this is a very key part of our operations and it's probably the most exciting part of the mission after the entry, decent and landing. There were seismometers sent to Mars on Viking but the seismometer was sort of the lowest priority instrument on the payload and so it did not get much in the way of resources or love. This shows a picture of the Viking spacecraft, a self-portrait and you can see the box that holds the seismometer.

You see the seismometer's sitting on the deck. The ground is back there and the problem is you really kind of want to have the seismometer and the ground kind of close together like in contact. That wasn't the case and because of the shaking of the spacecraft from wind and the poor coupling to the ground through the legs we never actually got any measurements of Mars quakes with that seismometer.

So on InSight we are going to a lot of trouble to get our instruments actually on the ground using a robotic arm and this is where we have our second video. This shows the spacecraft. So I'm going to start mine right now. And when you get it going it shows the arm - it grapples the seismometer, picks it up off the deck after we've released the explosive bolts that hold it on and it pulls it over and it puts it in the workspace. Now before that we've actually taken stereo pictures of this entire area in front of the spacecraft to find out places that are relatively level and are free of rocks and we'll decide which spot we want to put the seismometer on.

Once we got the seismometer down on the ground we actually go through a process of leveling the seismometer using legs that we have on the seismometer and we go back and we pick up the wind and thermal shield which is the big white wok that we have on the surface of the spacecraft and you can see that skirt kind of unfolded as we picked it up. It has three legs that hold it up off the surface and then the skirt comes down and seals around the seismometer so the wind won't blow the seismometer around and the temperature variations will be much smaller.

So once we get done with the seismometer we actually go back and we pick up the heat flow probe. The heat flow probe obviously has to be on the ground. We don't want to hammer through the spacecraft to get down there. So we pick it up. We pick up the surface part of the heat flow probe. It also has a cable that connects it to the spacecraft. Once we get the heat flow probe down we're all finished and ready to go into our two years of quiet operations. And this video took about a minute and a half. On Mars this takes two months because we stop and check every single point along the way and do it very, very carefully.

So the final slide in this presentation is just a picture from Spirit showing the sort of sunset on Mars and Gusev crater and the little dot up in the sky is Earth and I think this is very emblematic of our mission because we're actually going to Mars to explore the Earth. And so we have to gain insight into the Earth by exploring Mars.

So thank you very much and I don't know exactly how you handle questions but I'm open now for questions.

Jeffrey Nee: Thanks Bruce. So we'll just give people a second to unmute and they can ask their question.

Chris Thompson: I've got one Bruce. This is Chris Thompson, Solar System Ambassador. Just can you give us a little bit more information about the two-month deployment period for the seismometer and the head flow experiment and why - I understand you guys check everything but how much for that time is really looking at the ground and how much of the time is actually moving the instrument on the robot arm?

Bruce Banerdt: Okay so the movement on the robot arm from picking up off the deck to putting it on the ground actually only takes three or four minutes. So we actually are not hanging out in space for very long. So the actual deployment part of it is not that much slower than what I showed here. It's still slower but the robot arm only does it for a few minutes. Most of the time is spent taking pictures, analyzing the data, we grab onto the grapple and then we take pictures of that, we send it back to the ground and then we don't actually deploy it until we're sure that the grapple's been done properly.

That process takes a whole day because we send up commands in the morning, we get down data in the evening and so every time that we want to put ground in the loop of any operation that takes at least one day or one sol on Mars. And so each one of these operations that we want to check we have to stop and wait for the data to come down and so between taking information, analyzing it and then checking every step along the way it runs out to be about two months. But the actual arm activity is pretty quick.

Man 1: If Curiosity were to start its drill in a rock would InSight be able to pick that up and would that be of any use?

Bruce Banerdt: We're not that sensitive. That kind of vibrations you probably could see a few hundred meters away but not much farther than that. But that would be interesting information and in fact one of the things we're going to do is we're going to use the signal from the mole hammer, when it knocks itself down in the ground it moves a couple of millimeters with each hammer stroke.

So it hammers once every two seconds or so and so there are going to be several thousand hammer strokes to get that down to depth and we'll be picking that up on the seismometer we will be using that to actually look at the structure of the regulates, sort of the soil which we expect several like 10 or 15 meters of soil to be overlying, broken up rock and that will be overlying solid bedrock. And so we hope to be able to use those signals to map out sort of the stratigraphy of the soil around the lander.

Man 1: Thank you.

Man 2: Would you also plan to use say the weight from falling spacecraft to look at those impacts in the vibrations like it was done with the moon?

Bruce Banerdt: We don't have anything as big as the lunar upper stage. The things that come to Mars with our spacecraft are just the things like heat shield, the back shell and things like that. The upper stage which sends these spacecraft to Mars, we actually deflected away from Mars because they're worried about contamination. So for planetary protection purposes the rocket stages don't impact Mars. And so unfortunately, we won't be set up with our seismometers in time to be able to see the back shell or the heat shield impact which would be interesting but that's not going to work for us.

Man 3: I've got two questions. One about the potential for an ice field underneath the mole and second question about the cameras.

Bruce Banerdt: Okay. Well the subsurface in the equator - we don't think that there's ice there. If you do the thermodynamic analysis between the seasonal temperature variation and the diffusion of water out of the soil any ice that would be there would either be melted by the sun because we're in the equator and on Mars it's relatively warm at the equator or if you get down deep enough to get below the temperature cycles then it would be melted by the internal heat of the planet. So the ice in the soil is not expected to be present until you get up to, I don't know 30 to 35 degrees of latitude. So we're pretty sure that we won't run into actual ice in the soil.

We have two cameras on the spacecraft. And they're both based on cameras which have flown before. We have what we call our instrument deployment camera which is a Navcam from Curiosity, a spare Navcam from Curiosity which we've modified with a filter to make it into a color camera and that's actually mounted on the arm itself and we use the motion of the arm to point that camera. And so that's sort of a medium-resolution camera that you may have seen pictures from the Navcam on Curiosity or the Mars exploration rovers.

We also have a camera mounted just under the deck on the front of the spacecraft which is a Hazcam from Curiosity which has also been colorized and so that gives a panoramic - or fish-eye view of basically the entire space in front of the spacecraft. So we have two different angles for that deployment area. So the main reason that we put the camera is to pick deployment sites for each of the instruments but once we're done with that we'll be able to use our instrument deployment camera to take panoramas of the area around the spacecraft in color.

Darrell Heath: This is Darrell Heath, Little Rock, Arkansas Solar System Ambassador and I was just wondering if any of your seismological data might turn up water within the mantle. Is that something you might expect?

Bruce Banerdt: I don't think that we can actually resolve the change. I mean, when you put water into the mantle rocks it changes the seismic velocity a little bit it also changes the attenuation, the amount that the seismic waves get damped out as they move through. But I don't think we're going to be able to have that kind of resolution. Mostly this is a very basic seismic experiment. Like I said we're trying to get the real basic building blocks of the planet so just the size of the crust, the size of the core and the basic structure of the mantle whether there are any jumps in seismic velocity.

And if we get very lucky we may be able to see some of these second order effects like effects on attenuation and so on but water in the mantle is probably beyond our grasp for this experiment.

Man 4: Bruce you said the mole can go up to 5 meters down. What's the minimum depth you have to reach?

Bruce Banerdt: Well the minimum depth - we think we can probably make our measurement if we get down to just a little bit more than a meter and a half. So if the tail end of the mole gets down to a meter and a half that's probably enough to do it if we measure over the entire Mars year. That's cutting it close. What we'd like to be able to do - if we can get down to 5 meters we can basically make the measurement within a matter of a few weeks after the mole is finished.

Our requirement is to get down at least 3 meters and so everything's been designed, redundantly to get down to 3 meters but of course if we run into a big rock that'll stop the mole, it can't get past a big rock. It can actually sort of hammer itself around smaller rocks. If it hits a rock with an angle of 45 degrees or more it'll actually slide itself down and around that rock and continue on down. And smaller rocks it can actually break. It has a fair amount of force. It can break smaller rocks as well.

And so a big rock will stop us but if we don't run into such a rock - and we've done statistical analyses based on the number of rocks that we can see on the surface and based on that analysis we have about an 85% chance in the worst case and a better than 95% chance in the most likely case of getting down to at least 3 meters and at 3 meters we can determine that gradient in less than half of our mission lifetime.

Jeffrey Nee: Well Bruce I'll remind everyone that the can email questions to me later as well if you can't quite get through. But I had a question about the mole. Is there a reason why we do hammer versus say a drill bit to get deeper?

Bruce Banerdt: Well people have done a lot of research and a lot of development activity on drilling on Mars for getting down to ice, for getting samples up and so forth and it's a very complex system to actually run a drill that rotates and has a string which is connected to the top and so on. This mole is a very simple system.

And InSight is a discovery mission which is in a certain class of missions in NASA. We have a very strict cost cap which is roughly half a billion dollars. Turns out to land a spacecraft on Mars takes up most of that cost and so our instruments have to be very low cost. We've gotten around that in a couple of ways on this. Most of our instruments are being built in Europe and they're being contributed to the project at no cost.

But one of the reasons why we can actually penetrate to 5 meters is because the mole's a very simple system. It's just a little torpedo. It just winds a mass up on a spring and then releases it over and over again and by using that simple system at relatively low cost and low power and low mass we can do this experiment on Mars whereas if we had a drill that would take much more mass, much more power and we really can't afford it on the kind of budget that we have on this mission.

Steve Lee: This is Steve Lee at the Denver Museum. I had two questions. The first is do you have an idea of what time of day the landing is going to take place?

Bruce Banerdt: Yes we're landing in sort of the mid- to late afternoon. I think we have about two or three hours of good daylight for the solar panels before we go into night.

Steve Lee: Do you know what time on Earth that will be?

Bruce Banerdt: Oh actually I don't know what time it is on Earth on that day. That'll become really important at some point but I don't know what it is right now.

Steve Lee: Okay.

Sarah Marcotte: Yes Steve this is Sarah. We'll definitely get that information for those museums that want to do landing events.

Steve Lee: Okay that would be great. And the second question was just how much seismic noise do you expect the lander itself to create like wind gusts, flapping the solar panels or things like that?

Bruce Banerdt: We don't expect very much noise from the lander and of course "very much" is kind of a fuzzy term but we've done a lot of analysis on this. We've looked at all the different things on the spacecraft and there's really nothing on the spacecraft that will generate noise except for the solar panels. We've looked at the motions of the solar panels on Phoenix. We actually took some pictures of the solar panels and by looking at the blur on those pictures we can actually estimate the amplitude and the speed of that vibration and of course we can calculate what the resonances are and those then transmit themselves down to the lander feet.

And so our goal is to put the seismometer as far away from the feet as possible so it will kind of be as you saw in the video we'll kind of split the difference between those feet and get it as far out with the arm as we can as long as there's a clear space. But the amplitude of that noise is going to be definitely visible in the seismic records but it's not going to be large enough to really get in the way of our measurements.

David Seidel: How about the telemetry ribbons?

Bruce Banerdt: Those are shielded and they shouldn't give us a problem. The real problem, I mean, you're always worried about electromagnetic interference because there's signals and currents running all over the place in the spacecraft and those can create crosstalk and we've shielded things as best we can but we're actually going to do a test in about three weeks at Lockheed Martin to look at the electromagnetic interference patterns on the spacecraft and make sure that we haven't overlooked something.

David Seidel: How about the just flapping in the wind?

Bruce Banerdt: They don't really flap in the - it turns out they look like they're really flexible in this video but they're actually pretty stiff cables. The seismometer has five different layers of that flat cable and each of those is much thicker and tougher than ribbon cables that you may be used to in electronics. I had a sample of that cable at the Science Team meeting two weeks ago and I kind of whap it against my hand and you could really hurt somebody with one of those. They're kind of heavy.

And so they don't really flap in the wind very much but even so we've actually designed a weight that's in the middle of that cable that should kind of immobilize it on the surfaces just before it goes into the wind and thermal shield and we have some called a load shunt assembly which is sort of a horizonal loop. So when the cable comes up right next to the seismometer it goes into kind of a U loop and so if there's any vibrations coming up and down that cable that elastic loop is supposed to absorb most of it.

Jeffrey Nee: Bruce I know we're running over time and we want to be respectful of everyone's time including yourself of course. So maybe one more question if there is one.

Steve Lee: I'll try one. You mentioned if the heat probe runs into a large enough rock it's sort of game over. But say half of the probe is still sticking out of the ground. Would there be any possibility of grappling it again and picking it up and moving it?

Bruce Banerdt: No unfortunately we get one shot deploying it and then that's it. Once we've released the mole from its housing you can't really pick it up again. So if we run into a rock in the top meter or so the experiment's just going to be a loss unfortunately.

Steve Lee: Okay. Thanks.

Jeffrey Nee: So that's why you're going to take two months to really analyze everything, right?

Bruce Banerdt: That's right. And of course the bad thing is that rock could be one inch below the surface and all the analysis in the world is not going to help us then.

Jeffrey Nee: All right well fingers crossed. Thank you very much Bruce and of course again people know that if they have questions in the future they can just email me. Again my name is Jeff Nee and my email address is jnee@jpl.nasa.gov.

Thank you again to Bruce and thank you to Sarah for a wonderful presentation and to everyone on the line for really great questions.

END